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PECAN GRAFTING METHODS AND WAXES¹

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INTRODUCTION

It is a common practice to top work native seedling trees or those of undesirable named varieties of pecan (*Carya pecan* (Marsh.) Engl. and Graebn.) with varieties thought to be more productive, to be resistant to infection by fungi causing disease, or to bear nuts having greater commercial value. Many attempts to top work trees have been unsatisfactory owing to partial or complete failure to establish the new top, to damage in the process by insects and wood rots, to scions broken out by wind, or to trees weakened by drastic pruning. The frequent occurrence of such unsatisfactory results warranted a study of the grafting procedure to learn their cause and to devise preventive methods.

REVIEW OF LITERATURE

Although grafting of fruit trees is a very old art, the first successful vegetative propagation of the pecan apparently was accomplished in 1822 by Landrum (17, 18),² who succeeded in budding the pecan onto a hickory. Taylor (35) reported that the first propagation of a pecan to be given a variety name was done in 1846 or 1847. Pecans from these grafted trees were exhibited at the Centennial Exposition at Philadelphia in 1876 and the variety was afterwards named Centennial. Taylor (34) stated that the pecan is more difficult to propagate than most fruit trees, and that the best method was annular budding done early in the summer on 1- or 2-year-old seedlings. Fuller (10) quotes correspondence from P. J. Berckmans, a nurseryman, as stating that in his nursery 15 to 25 percent of the scions set by the use of the crown graft on 1-year-old seedlings grew. The term "crown grafting" has been used to designate a number of different methods of grafting,

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² Italic numbers in parentheses refer to Literature Cited, p. 28.

but the method most commonly so designated was that in which the scions were set by whip grafting near or below the ground line, and it is probable that this is the method referred to by Berckmans.

Oliver (21) described several methods of budding the pecan and recommended a modification of the patch method in which an I incision is made in the stock for receiving the bud. Sitton (28), working with the black walnut, found that this method was undesirable because the presence of the flaps of bark over the patch carrying the bud made it difficult to press the bud tightly against the stock. Many patches of bark grew, but most of the buds died because of failure to establish union directly under the bud. Easley (7) recommended the chip- and patch-bud method for top working pecan trees. Reed (25) stated that more pecan nursery trees have been propagated by annular budding, with its modification, than by all other asexual methods combined. Hume (15, 16) described several methods of budding and grafting and stated that expert propagators were satisfied with 75 percent of living buds or scions, but that most others were less successful.

Evans (9) probably was the first to suggest the use of the bark graft on the pecan, although it had long been used with other fruit trees, as reported by Sharrock (27), Burbidge (2), and many others. The first report of the use on the pecan of the inlay-bark graft with the scion nailed to the stock was probably made by Wenzel (36) in 1924, although the method had apparently been used for some years previously on fruit trees. Wenzel (37) called attention to defective unions that resulted from the bark-slot method caused by the bark at the sides of the slot interfering with the normal growth of the scions.

McMurrin (19) and Demaree (6) discussed the danger of injury to top-worked pecan trees by wood-rotting fungi that gain entrance through improperly made pruning wounds and reported that stubs are very susceptible to wood rot. Smith et al. (30) found that trees headed for top working most severely had more wood rot in wounds than trees less severely headed; also, that the smaller wounds had less rot than larger wounds. According to Heald (14) the wood-destroying fungi are for the most part parasites that gain entrance through pruning wounds or other mechanical injuries. Many of them make their best development in the heartwood; others start in the heartwood and later advance into the sapwood. *Pleurotus ostreatus* Fr. is classified by Stevens (31) as saprophytic and *Polyporus hirsutus* Fr. as a wound parasite. Essig (8) reported that *Schizophyllum commune* Fr. is able to gain entrance into trees through pruning wounds or other points of mechanical injury, and Putterill (24) demonstrated that the latter fungus is able to grow on living wood, which it kills. Demaree (6) reported that infection of wounds can usually be prevented by painting the cut surface thoroughly with an antiseptic tree-wound dressing.

In a study of defective graft unions in the apple and pear, Bradford and Sitton (1) found a close analogy between graft unions and the healing of wounds where no graft was involved. They report that subsequent to wounding, new tissue is laid down in definite relation to the remainder of the tree. Wounds formed by amputation of a lateral branch close to the main branch heal by growth of tissue from the sides primarily but also to some extent from the basal and apical edges of the wound. A decapitation wound, made by cutting a branch back

to a side limb, is similar to the amputation wound. It differs in that healing is slower because a larger proportion of the tree above the wound has been cut away; also, the tissue readjustment may be more radical. The new vascular tissue forms approximately longitudinally to the new stem, which is a composite of the old main stem and the new leader. On the old main stem, opposite the new leader, the new tissue may be formed in a direction almost transverse to that of the old. Growth on the side opposite is slower than along the sides adjacent to the new leader. There is a similar reorientation in the new tissue subsequent to grafting where the stock is cut off squarely. Where the union is established between scion and stock at the top of the stub, tissue develops and extends over the top adjacent to the scion. Where the contact is established below the rim, no new wood forms at the top of the stock and the cambium and bark die. A scion set so that contact is not established at the top of the stock is like cutting back to a small side branch and leaving a stub.

DEFECTS RESULTING FROM INCORRECT METHODS OF GRAFTING

A study was made of pecan trees in various localities in Louisiana that had been grafted or budded in order to change the top to a desired variety. Included in this study were trees that apparently had been top worked with complete success and others that showed various types of defects. These defects were analyzed and classified to clarify the problem.

Examination of 100 pecan trees on which an attempt had been made by the owner of the orchard to top work to the Success variety showed that many trees had been so drastically cut back that severe injury resulted from sunscald and only a small percentage of scions lived. Borers and wood-rotting fungi had damaged the trees still further.³

The type of injury referred to as sunscald occurs on a portion of the tree previously shaded but exposed to the direct rays of the sun from the southwest after cutting back. It apparently occurs during the growing season immediately following the cutting back, but the effects are usually not observed until the following spring when it is evident that the bark and cambium⁴ are dead. Chandler (5), Goff (11), and Harvey (13) considered that the cambium is killed as a result of the high temperatures caused by the sun's rays striking the old bark under conditions that reduce the transpiration stream. Chandler (5) reported that the temperature of the cambium had been measured as high as 131° F. on the sunny side of a branch. Harvey (12) reported that the temperature of the cambium under dark-colored bark was higher than under light-colored bark when both were exposed to sunlight in winter. These reports, and the observations made during this study, indicate that if sufficient foliage is left above the area exposed to the sun little injury will result.

³ The borers and fungi responsible for this damage were not identified, but the pecan borer (*Cenopia scitula* (Harr.)), the American plum borer (*Euzophera semifuneralis* (Walk.)), and the flatheaded apple tree borer (*Chrysobothris femorata* (Oliv.)) have been collected from other grafted pecan trees and were identified by the Division of Insect Identification, Bureau of Entomology and Plant Quarantine. From pecan wood showing evidence of wood-rotting fungi *Panus rudis* Fr., *Pleurotus ostreatus* Fr., *Polyporus crispus* (Pers.) Fr., *Polyporus (Polystictus) hirsutus* (Wulf.) Fr., *Portia ambigua* Bres., and *Schizophyllum commune* Fr. have been identified by J. A. Stevenson, Division of Mycology and Disease Survey, Bureau of Plant Industry.

⁴ In this circular the terms "wood," "cambium," and "bark" are used as general terms. The xylem of the stem is referred to as "wood." No distinction is made between the initiating layer, the xylem mother cells, and the phloem mother cells, but the entire differentiating, immature region between the xylem and the phloem is referred to as "cambium." All of the tissues lying outside of the cambium are referred to collectively as "bark."

In the cases examined in this study the area injured by sun scald was attacked by the flatheaded apple tree borer and infected by wood-rotting fungi, usually *Schizophyllum commune*. No evidence was observed to show whether or not the tree would have recovered from the sunscald if the borers and wood-rotting fungi had not gained entrance.

Examination of the grafts made on these trees showed that the scions had been inserted under the bark and tied in with waxed cloth. The scions that grew had not established union at the rim of the stub. New growth extended from the topmost point of union diagonally



FIGURE 1.—Poor unions. *A*, A defective graft 2 years after grafting. Only one scion lived and its union with the stock was about 2 inches below the top of the stub. The stock died back and wood-rotting fungi gained entrance and had progressed down the stock for more than 2 feet. *B*, Section through the base of a sprout produced after cutting back a large branch, showing the poor union resulting from the thick bark on the branch.

downward around the stock on each side and met on the side of the stock opposite the scion from 3 to 12 inches below the top of the stock. The part of the stock above the new tissue died, having been invaded by borers and wood-rotting fungi (fig. 1, *A*).

In another locality trees were examined that had been top worked by budding into water sprouts produced after they were severely cut back. In most cases the water sprouts originated some distance from the apex of the stub; the portion beyond the water sprout had died and had been invaded by wood-rotting fungi. Although the scion buds were growing the trees were weakened by the wood rot. To avoid such conditions careful follow-up work is necessary and should include cutting off the projecting stub close to the shoot so as to facilitate healing. Wounds should be treated to prevent the entrance of wood-rotting fungi.

Many water sprouts were found to have such poor anchorage to the parent branch because of its thick bark that they were easily broken out. A shoot 1 inch in diameter may have a shoulder on the outside of the bark on the parent branch 2 or 3 inches in diameter and may appear to be well anchored, but it may be very weak. The thick, tough bark of the parent branch seems to retard the development of the shoot where it passes through the bark, particularly periclinally to the parent branch (fig. 1, *B*). Borers had gained entrance around the point of attachment of many of the shoots and had further weakened their anchorage. Frequently such shoots break out in the wind.

These investigations did not include a study of methods for avoiding the weak anchorage of shoots, but in a limited number of cases the rough outer bark was pared away, exposing the white, soft, inner bark as advocated by Woodard, Romberg, and Willmann (38). Shoots arising from under this pared area expanded and pushed the soft bark outward and thus established a good anchorage. These studies did not show how much of the rough bark may be pared away without injury to the latent bud, nor how much it is necessary to pare away to permit good anchorage.

In a third orchard, pecan trees had been top-worked by the use of grafts set on the side of branches that were cut back, leaving a stub 12 inches or more projecting beyond the graft. These stubs died, and wood-rotting fungi gained entrance. This could have been largely prevented by cutting the stubs close to the grafts and properly protecting the wounds during the winter following the grafting; however, instances were observed where wood rot had progressed downward beyond the point of attachment of the scion before the end of the first growing season. Another objectionable feature of the side graft is that it does not form a strong anchorage to the stock, because the new tissue is laid down similarly to that on a decapitation stub unless there are shoots beyond the graft, in which case the graft may grow very slowly or die after starting. If the stub extending beyond the graft is not cut off the union is never good, and the wound made in setting the scion offers an entrance for borers and wood-rotting fungi.

In other orchards, where the method of grafting and the workmanship were good, the dieback of the stocks was apparently due to damage by borers, which destroyed the cambium and new callus around the top of the stock and under the scions. Many grafts that had broken out at the union have been examined, and without exception the breakage was due to weakness of the union. All of the breaks examined were characterized by lack of union at the top of the stub and by growth that did not anchor the scion firmly to the stock.

Top-worked trees that had none of these defects were studied and showed clearly that the defects are not necessarily concomitant with top working by grafting. These studies indicate that the difficulties encountered in top working pecans by grafting consists of (1) sunscald, (2) stubs projecting beyond the graft or the budded shoot, (3) poor unions at the top of the stub, (4) borers working in the callus under the graft, and (5) wood-rotting fungi.

Grafting trees involves more or less drastic pruning either before or after the grafting is done. The response of pecan trees to severe pruning was studied, and it was found that the dieback observed in the grafts resembled that following certain types of pruning. The

growth response of the apple and pear following cutting back to an existing lateral has been described by Bradford and Sitton (1), and a

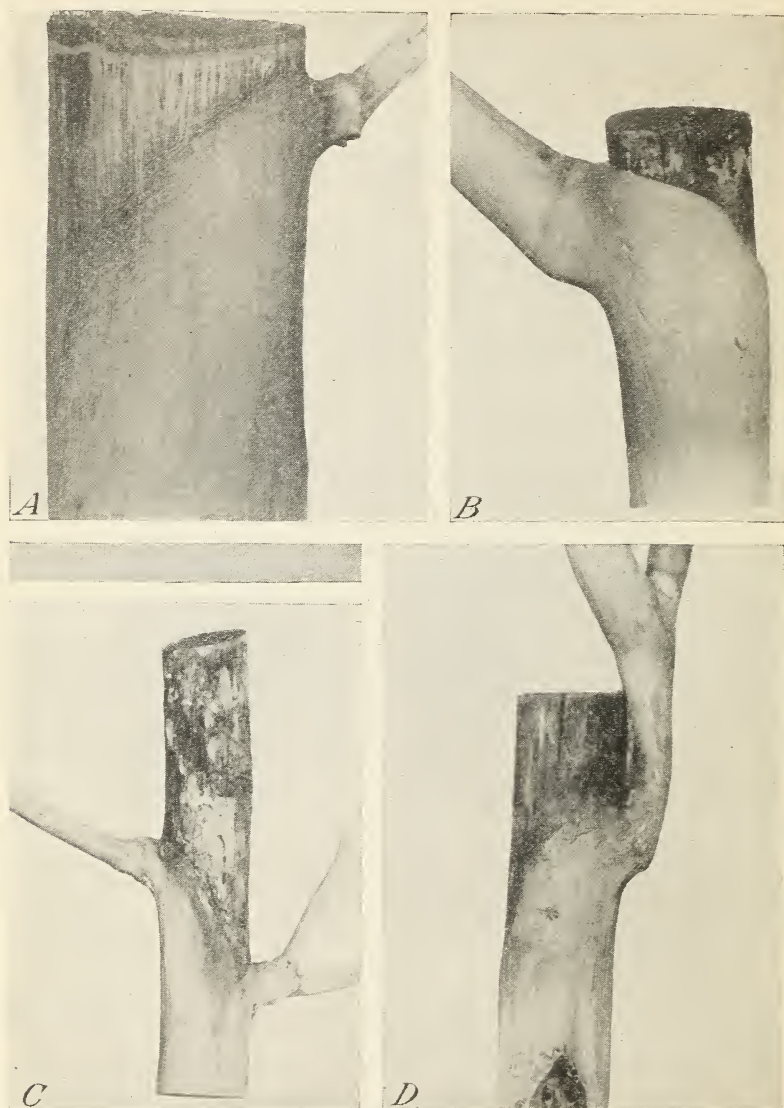


FIGURE 2.—To prevent dying back of cut back branches new xylem growth must be made to the apex of the stub: *A*, A cut-back branch with the bark removed to show the new shoot and the course of the new xylem tissue formed after the wound was made; *B*, 2 years' xylem growth after branch was cut back beyond a very small lateral; *C*, after cutting back, two sprouts grew and new xylem tissue developed along a line from the apical to the basal shoot; *D*, graft union was not made at apex of stock which died back.

similar response was observed in the pecan. Grafting, however, usually involves cutting off a branch some distance beyond any existing lateral, and the growth response is more comparable to that follow-

ing the development of water sprouts from latent buds on a decapitated stub. In the specimens of the latter class examined, the orientation of the new vascular tissue, especially along its upper margin, was very different from that of the old branch. A representative decapitation wound and the new growth resulting is shown in figure 2, *A*. The bark has been removed to show the new xylem tissue. About 2 weeks had elapsed since the beginning of growth of the shoot when the stub was removed from the tree. The early stage of the change in orientation of the vascular tissue is clearly shown. Very little new tissue developed distally to the shoot. On each side of the shoot the new tissue radiated outward and downward, and for about 1 inch on each side of the shoot the upper margin of the new tissue was almost transverse to the old stem. There it turned downward and this trend increased with additional distance from the shoot. At about two-thirds the distance from the shoot to the opposite side of the stub, the margin of the new tissue was almost parallel with the old branch. The margin from the two sides met at about 5 inches below the apex of the stub. The old tissue above the margin of the new showed decline due to insufficient nutrition and probably would have died within a short time. A more advanced condition of a similar wound is shown in figure 2, *B*. The portion of the stub projecting beyond the new growth had died, borers and wood-rotting fungi had gained entrance.

The amount of dieback was greater on stubs larger than that just described and less on stubs smaller. Frequently on stubs about 1 inch in diameter the new tissue was laid down transverse to the old stem almost to the opposite side from the shoot. Where the lateral shoot developed at the apex of the stub a much smaller portion of the stub died, and in some cases where the stub was small there was no dieback.

The development of more than one shoot on the stub resulted in a somewhat different course of development of the new tissues. Where two shoots occurred approximately opposite each other, which was rare, the growth from each shoot tended to extend diagonally downward around the stub in the manner previously described, but frequently when about one-third the distance between the two branches had been covered, the new vascular tissues turned nearly transverse to the stub and met the growth from the other branch. The amount of dieback was not so great as on stubs having only one shoot; where two shoots were present and one developed more basally on the stub than the other, the amount of dieback was sometimes as great as where only one branch occurred on a stub, with the margin of the new tissue extending directly from the apical to the basal shoot (fig. 2, *C*). The effect of the size on the stub having two shoots was similar to that for one shoot in that the dieback was less on small stubs and greater on large ones.

When a single scion was set on a stub and union was not made at the apex, the new tissue laid down was similar to that formed when a single shoot grew, and the portion of the stub extending beyond the new growth died (fig. 2, *D*). Where union was established at the apex of the stub the dieback was not so extensive and in many cases there was no dieback (fig. 3, *A*).

If no dieback occurred the vascular tissue subsequently formed extended over the rim and completely covered the wound. Many

such grafts were not invaded by wood-rotting fungi. Frequently grafts of one scion to the stub had considerable dieback if the stub was large. It seems advisable to set more than one scion if the stub is much larger than 1 inch in diameter.

On stubs where two scions grew but union of one or both was not complete to the apex of the stub, some dieback occurred but usually it was not so extensive as where only one scion grew; frequently the final result was just as serious, for wood-rotting fungi invaded the deadwood, and once they had gained entrance they continued to advance in the heartwood. Where two scions united at the apex of the

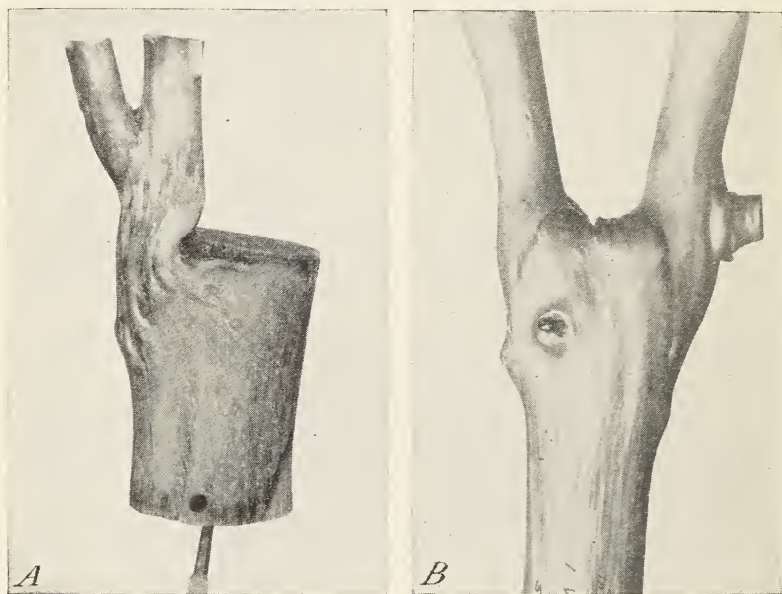


FIGURE 3.—Pecan graft unions with bark removed to show new tissues formed after the grafts were made: *A*, Only one scion was set with union being made almost to the apex of the stock and new xylem tissue extended around and within one-eighth inch of the apex of the stub; *B*, an excellent graft union in which new xylem growth has extended across the top of the stub and firmly anchored both scions to the stock.

stub there was no dieback and no evidence of wood rot (fig. 3, *B*), where the grafted stub was not more than $3\frac{1}{2}$ to 4 inches in diameter. On stubs much over 4 inches in diameter the new growth usually did not extend to the apex of the stub for the entire circumference of the wound, but there was an area on each side midway between the scions that died. The amount of dieback was less where more than two scions grew, but the large stubs were frequently invaded by wood-rotting fungi, even where there was no dieback. The grafting of large branches results in a larger wound and exposes a greater amount of heartwood than does the grafting of small branches. The larger the wound the longer the period between wounding and the covering of the wound by new tissue, and the dead heartwood is exposed to infection by fungi for a longer time. It is therefore not advisable to graft a branch at a point where it is larger than $3\frac{1}{2}$ to 4 inches in diameter.

METHODS OF GRAFTING STUDIED

Experiments were initiated in the spring of 1934 to determine the cause of poor unions and to find a method of top working pecan trees that would insure a high proportion of living grafts having good unions. Previous experiments and the report of Price (23) and others indicated that the bark-graft and patch-bud methods of top working usually result in high percentages of grafts or buds that grow. The investigations being reported were confined to the bark graft, of which eight modifications were used, but in all methods the scions were inserted at the distal end of the cut-off stock. There are many modifications of the bark graft, but they are essentially variations of two types. The scion may be inserted under the slit bark of the stock or it may be inserted in a slot or recess made by the removal of a piece of bark of the stock of such size and shape to accommodate the prepared scion. Some of the modifications used have been described and designated by name by different authors; others have been advocated but not given a name. The modifications of the bark grafts used in these experiments were as follows.

A.—The method generally referred to as bark graft and apparently first described, although somewhat indefinitely, by Sharrock (27), and more recently described for use on the pecan by Evans (9), Reed (26), and Woodard, Romberg, and Willmann (38). In this method most of the rough bark of stock was pared off, exposing the light-colored inner bark, but not the cambium, and a single vertical cut through the bark was made in this area. The scion was cut with a bevel 2 to 2½ inches long, drawn out to a sharp point; it was pointed by two short beveled sloping cuts at the back of the tip so that it would slip under and raise the bark of the stock. The scion was then slipped under the bark and secured by binding it to the stock with several wraps of waxed cloth, which was also used to cover the cut surface of the stock. The tip of the scion and other exposed cut surfaces not covered with cloth were covered with a hand grafting wax.

B.—A modification of the bark graft as suggested by Wenzel (37). The scion was prepared and inserted as in method A but was nailed to the stock with one or two small-caliber flathead nails three-fourths of an inch long, and all cut surfaces were covered with a melted black wax.

C.—The inlay-bark graft method, as described by Peck (22) and Sitton (29). The outer bark was pared from the stock as in method A and the scion was cut with a long sloping bevel 2 to 2½ inches long. The basal end of the scion, at a point where it was about one-fourth of an inch thick, was cut square across. The beveled part of the scion was held against the pared area on the stock, the bark was cut and a strip just large enough to accommodate the scion was removed from the stock, forming a recess with the cambial cells on the surface of the wood exposed. The bevel of the scion was placed in the recess against that surface and one or two nails were used to secure the scion to the stock. All exposed cut surfaces on both scion and stock were covered with a melted light-colored grafting wax. (Table 3, No. 7.)

C'.—Same as C in all respects except that a black wax was used. (Table 3, No. 3.)

D.—The bark-slot graft method as described by Wenzel (36) and Woodard, Romberg, and Willmann (38). The scion was cut with a

bevel as in method C, then a short bevel was cut on the opposite side of the basal end, forming a chisel edge. The bark of the stock was pared and cut as for method C and a strip just wide enough to accommodate the scion was lifted but left attached at its basal end. The scion was slipped under the strip of bark, nailed, and the strip cut at the top of the short bevel. All parts were waxed as in C but with black wax.

E.—The graft was made as for C, except that it was covered with waxed cloth and hand wax as in A.

F.—The graft was made as for C, but the scion was not nailed. It was bound with waxed cloth and the top of the stock was covered with waxed cloth and hand wax as in A.

G.—The graft was prepared as for C, except that the bevel on the scion was planed to form a perfectly flat straight surface and black wax was used.

H.—The graft was prepared as for C except that the bark at the edges of the bevel was pared away until the cambium apparently was exposed and black wax was used. It was not always possible to expose the cambium, for in some cases the paring may not have been deep enough and in others too deep.

I.—The graft was prepared as for C except that the stock was cut back in March about 2 months prior to the date of grafting.

Bradford and Sitton (1) showed the desirability of obtaining union of the scion at the apex of the stock, as well as along the sides and at the basal end. In order to obtain such a union the scion must be placed so that callus from it will be as close as possible to that from the apex of the stock. Callus arises on the scion primarily from the edge of the cambium exposed when the bevel is made on the scion. Callus may arise on the stock from any uninjured cambial cells remaining on the surface of the wood exposed by the removal of the strip of bark, but union is accomplished most readily by the tissue arising at the margin of the bark. In this study all of the scions were placed with about one-half inch of the bevel extending beyond the apex of the stock. The bevel at that point was almost its full width and such a placement of the scion reduced to a minimum the space between the cambium of the scion and that at the apex of the stock.

Usually two scions were set on each stock, but some grafts were made with only one. The latter were used in the study of the formation of new wood reported on pages 7 and 8.

PROCEDURE

Scion wood was collected from the Stuart variety of pecan just before the trees began growth in the spring. The wood was packed in moist sphagnum moss and stored in commercial cold storage at a temperature of approximately 34° F., but at times during a part of the storage period the temperature was considerably higher. This resulted in the swelling of many buds on the scions before the grafting was done, and the percentage of "take" was thereby materially reduced. Scion wood was more carefully selected and stored in 1935 and 1936. Two-year-old wood that had made 18 inches or more of linear growth during its first year and that was between three-eighths and five-eighths of an inch in diameter was used. Wood that seemed to be low in food reserves was discarded. During the storage period in these 2 years the temperature was approximately 34°. During the grafting season, wood for each day's work was removed from storage in the morning.

Seedling pecan trees growing in the Red River bottom land were used as stocks. Grafts were inserted in the main trunk about 6 feet from the ground, at which height the trees averaged approximately 2½ inches in diameter with a range of from 2 to 4 inches.

The trees were closely spaced and for the most part had no branches below the point where the grafts were inserted.

Grafting was done in the latter part of April, as soon as the bark of the stock slipped freely, and was completed within 5 days, except in 1934 grafting by method C was done May 30, and methods A, C', and I were repeated on that date. The stock was cut off with a saw and the scions were immediately set and waxed, or otherwise covered. Two covering materials for protection of the grafts from loss of moisture were used at first. Some of the grafts were covered with waxed cloth and hand grafting wax; others were covered with a melted black brush wax composed of 5 pounds of rosin, 1 pound of beeswax, one-half pound of lampblack, and one-fourth pint of raw linseed oil. It soon became evident that the black wax was injurious to the pecan, and it was modified by the substitution of talc for the lampblack and by the omission of the linseed oil. The waxed cloth was prepared by impregnating unbleached drill with melted hand wax composed of 4 parts of rosin, 2 parts of beeswax, and 1 part of tallow.

RESULTS

Data showing the percentage of scions growing and those having good unions for the grafting done in the seasons of 1934, 1935, and 1936 are given in table 1. Due to the use of superior scion wood and to better storage conditions the percentage of scions that grew in 1935 and 1936 was higher than in 1934. Only those grafts were considered as having good unions where the scion had united with the stock at the rim of the wound on the stock, was free of damage by borers and wind, and showed no evidence of infection by wood-rotting fungi. A graft of this class is shown in figure 3, B.

The most satisfactory method used was the inlay-bark graft with the scions nailed to the stock and all exposed cut surfaces covered with a wax composed of 5 parts rosin, 1 part beeswax, and one-half part talc (table 1, method C). Grafts made by this method resulted in a higher percentage of growing scions and a higher percentage of good unions than any other. The first year 90 percent of the scions set by this method grew and 85 percent had good unions. This was much better than the results of any other method, under conditions that were not as favorable as those of later years. In the other 2 years every scion that grew had a good union. No scion set by this method broke from the stock as did some of those set by other methods.

Grafts set by the same method but covered with a wax having the talc substituted by lampblack as the filler (table 1, method C') were not satisfactory, because the percentage of scions that grew was very low in 1934 and in other years lower than with talc as the filler. In 1934, one-fourth of a pint of raw linseed oil was added to the wax as recommended by Cardinell and Bradford (4). Evidence of injury to the cambium of the stock and scions was observed where this wax was used. Later experiments indicated that this injury was due in part to the oil. Unions were not all complete to the top of the stock, probably because the wax became soft when exposed to sunlight and ran downward leaving the top of the graft somewhat unprotected.

TABLE 1.—*Percentage of scions growing and having good unions under various methods of grafting*

Method used	Scions set and growing						Scions having good unions		
	1934		1935		1936		1934	1935	1936
	Set	Growing	Set	Growing	Set	Growing			
A.—Scions inserted under the bark of the stock, covered with waxed cloth and hand-grafting wax which held the scions in place.	Num-ber 90	Per-cent 63	Num-ber 100	Per-cent 94	Num-ber 52	Per-cent 44	Per-cent 0	Per-cent 25	Per-cent 10
B.—Scions inserted under the bark of the stock, nailed to stock, covered with melted black wax.	58	44					0		
C.—Scions inlaid in recess in bark of stock, nailed, covered with light-colored wax.	29	90	58	90	50	100	85	90	100
C'.—Scions inlaid in recess in bark of stock, nailed, covered with black wax.	40	34	100	87	52	48	10	50	30
D.—Bark-slot graft, with lip of bark of stock extending over lower end of scion, nailed, covered with black wax.	25	36	60	80			6	40	
E.—Scions inlaid in recess in bark of stock, nailed, covered with waxed cloth and hand wax.			53	96				90	
F.—Scions inlaid in recess in bark of stock, not nailed, bound with waxed cloth and top of stock covered with waxed cloth and hand wax.	39	56	50	70			30	40	
G.—Same as C except the bevel of the scion was planed before insertion; covered with black wax.	67	34							
H.—Same as C except bark of scion at edges of bevel pared, covered with black wax.	60	17							
I.—Same as C. Stock cut in March prior to grafting in May.	45	20							
A.—Repeated May 30.	52	15					0		
C.—Repeated May 23.			25	80				80	
C'.—Repeated May 30.	72	20					0		
I.—Repeated May 30.	55	21							

Use of the black wax the latter part of May was followed by the low percentage of scions that grew, and no good unions were formed. The light-colored wax gave almost as good results at that time as earlier in the season.

Grafts set by the same method but covered with waxed cloth (table 1, method E) resulted in a high percentage of scions that grew, but many of them were damaged by borers and the percentage of good unions was lower than with similar grafts covered with light-colored wax.

Of the grafts prepared as for the inlay method but not nailed, and covered with waxed cloth instead of melted wax (table 1, method F) 56 and 70 percent of the scions set grew in 1934 and 1935, respectively. The percentage of good unions was much lower than for method C, owing to failure of the scion to unite at the apex of the stock and to damage by borers. Bradford and Sitton (1) showed that union between stock and scion is not accomplished until their callus tissues press with considerable force against each other. The waxed cloth apparently slipped or stretched enough so that the growth of the callus tissues pushed the scion away from the stock, causing a depression between the scion and the stock along the line of union (fig. 4, A).

Such depression was not evident in the unions made by method C (figs. 3, *B*, and 4, *B*). Transverse sections of unions similar to that of figure 4, *A*, showed that the scion had been pushed 2 to 15 mm. from the stock. Frequently the first-formed group of parenchymatous cells arising from the scion were separated from those from the stock by a suberized layer, and union was established only as later-formed cells pressed together so that suberization did not occur. A transverse section of a pecan graft that had not established union at the apex of



FIGURE 4.—Defective and good inlay bark-graft unions. *A*, The scion was tied in with waxed cloth that did not hold it tightly to the stock and the callus tissues pushed it away from the stock; *B*, the scions were nailed in and union was established at the bottom and along both sides extending to the apex of the stock, forming a strong union. Subsequent growth has pushed over the top of the stub, firmly anchoring the scions.

the stock is shown in figure 5. The section was cut approximately 15 mm. below the apex of the stub, and at that level there was no union on the right side of the scion. Parenchymatous union had been established at *A* on the left side, but had there not been better union below this point the graft could not have survived for the union was not complete, as indicated by the suberized layer at *B*. The periderm that separated the stock and scion tissues on the right was lost in sectioning.

When the union was not complete at the apex of the stock the portion of the stock extending above the point of union became in effect

a projecting stub and died back. Grafts of this kind were extremely susceptible to borer infestation, which gained entrance to the wound through the space between the scion and the stock. Many such grafts were injured by borers after they had made several months' growth, and many of the growing scions were broken away from the stock by wind because they did not have a strong anchorage to the stock.

The scions may make a good growth even though the unions are not complete to the apex of the stock, and this growth causes the scion tissue to be pushed over the bark at the apex of the stock. Wenzel (37) reported a similar condition but apparently did not recognize its true significance, for he considered the bark of the stock interfered with normal growth and resulted in a weak union. Apparently the

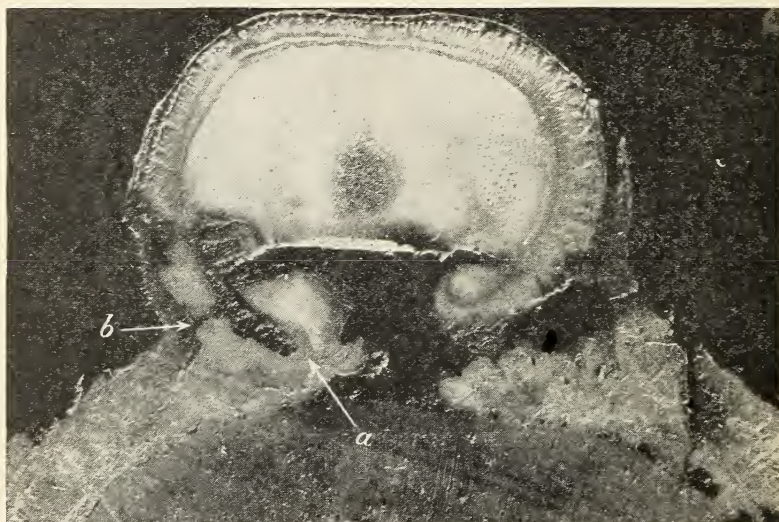


FIGURE 5.—Transverse section 15 mm. below the apex of a pecan graft which had not formed a union at the top. There was no union on the right side at this level. Periderm (lost in sectioning) had separated the callus tissues of the stock and scion. Parenchymatous union was established at A, but a suberized layer separated the callus tissues at B. Union was established at a lower level.

failure of the union at the apex of the stock is responsible for, rather than the result of, the tissue growing over the bark. Where union was established at the apex of the stock, the new tissue was formed under the bark and lifted it from the stock (fig. 4, B) and in no case did the bark interfere with the union. When the bark of the stock was excessively thick, paring away part of it prior to inserting the scion reduced the resistance of the bark to the expansion of the new tissues and facilitated the growth of the tissues into a smooth strong union.

Grafts made by inserting the scion under the bark (table 1, method A) responded in a similar way to those made with the inlay graft with the scions secured by wax cloth instead of nailing (table 1, method F). In both methods the percentage of growing scions was very nearly the same but of those failing to establish union at the rim of the wounds the percentage was greater in method A. This was possibly due in part to damage to the cambial cells on the stock caused by pushing

the scion over them, and in part to the increased space over which it was necessary for the new callus of the stock to grow in order to establish contact with the callus of the scion.

Use of method A during the latter part of the season resulted in a low percentage of scions growing and in no good unions.

In 1934, when the same method of inserting the scions was used except that the scions were nailed to the stock and the graft covered with black wax (table 1, method B), the percentage of growing scions was small and no good unions were formed. The injury caused by the black wax was especially evident, and injury by borers occurred on every graft. This method was so unsatisfactory that it was not used after the first year.

The bark-slot graft (table 1, method D) resulted in approximately as high percentages of growing scions as did the inlay-bark graft when the same covering material was used, but the percentages of good unions were somewhat lower. Growth of callus under the lip of bark at the lower end of the scion lifted the lip and broke the wax cover, after which borers entered through the break and damaged a large number of scions. Leaving a lip of bark is advocated by some authors (37, 38) on the grounds that the first union is often established there. This may be true, but the increased danger of injury by borers makes the practice hazardous. No increase in the percentage of growing grafts and no saving of time in grafting resulted, so it seems inadvisable to leave a lip of bark protruding over the lower end of the scion.

Planing the bevel of the scion (table 1, method G) resulted in no increase in percentage of growing scions; paring the bark at the edge of the bevel (table 1, method H) reduced the percentage of growing scions as compared with the regular inlay method. Both of these modifications required additional time in setting of the scion, and since they gave no increased percentage of growing scions nor improved union of those that did grow, there seems to be no justification for their use.

Cutting back the stock while dormant and some time in advance of grafting (table 1, method I) resulted in a smaller percentage of growing scions as compared with grafting at the time of cutting back. This seemed to be true both if the wound on the stock was covered with a wound dressing when cut or if it was left uncovered. Buds on the stock started growth before the grafts were made or soon after, and apparently inhibited callus formation around the graft. If the stocks were recut enough below the original cut it might be possible to avoid the stimulation caused by the first cut. In this experiment the stocks were recut 2 to 3 inches and a few as much as 10 inches below the first cut, but no record was made of the response of those cut to different lengths because there were too few for the differences, if any, to be significant.

EFFECT OF POSITION OF SCIONS

Several practical propagators have said that scions placed on the southwest side of a stub are more likely to fail than if placed otherwise. While this experiment was not planned to give information on this phase, the data show that this was true for grafts covered with black wax; with other coverings the difference between the scions growing on the southwest and on other sides was so small as to be within experimental error. This is shown by the data of table 2, which were taken

in the 1935 and 1936 experiments on the effectiveness of 60 covering materials and which have been arranged to show the place effect. A total of 2,771 scions were set without regard to the points of the compass, and of these 339 were set on the southwest side of the stub. Of those scions set on the southwest side and covered with black wax, 64 percent failed to grow; of those set on the other sides of the stubs, only 17 percent failed to grow. Of the scions set on the southwest side and covered with materials other than the black wax, 21 percent failed to grow; of those set on other sides and covered with the same materials, 20 percent failed to grow. All scions set and covered with wax No. 5 (see table 3) grew whether placed on the southwest side or elsewhere.

TABLE 2.—*Relation of the percentage of scions growing to the position of the scion on the stock in reference to points of compass*

[Data for seasons of 1935 and 1936 combined]

Position of scion and wound covering	Scions set	Scions growing		Scions failing to grow
	Number	Number	Percent	Percent
Scions in 60 groups covered with 60 different materials, set at random.....	2, 771	2, 213	80	20
Scions set on southwest side, covered with black wax.....	33	12	36	64
Scions set on other sides, covered with black wax.....	121	101	83	17
Scions set on southwest side, covered with materials other than black wax.....	306	241	79	21
Scions set on other sides, covered with materials other than black wax.....	2, 311	1, 859	80	20

WAXES

MATERIALS AND METHODS

Results of the first season's work showed the need of a more suitable wax for covering the pecan grafts than those tested, therefore, investigations of various covering materials were undertaken. Cardinell and Bradford (4, p. 36) listed the qualifications for a good covering material:

* * * (1) it would exclude air and fungi and retain the moisture of the wood; (2) it would contain no material that will injure live tissues in the strength at which it is used; (3) it would not crack in cold weather; (4) it would not run in hot weather; (5) it would be semi-permanent in possession of its various virtues; (6) it would have more or less elasticity to accommodate itself to changes in dimension of stock and cion consequent upon growth.

For use on the pecan two additional characteristics are needed: (1) The material must exclude borers, and (2) it must set quickly in the presence of sap, because the pecan "bleeds" when cut in the early spring.

Several commercial grafting and wound-dressing compounds were obtained, and other materials were made according to various published formulas. In addition, many original formulas were prepared, using some materials that apparently have not been used heretofore in grafting compounds. In this circular all materials used for covering grafts will be referred to as waxes, although most of them had a larger proportion of resins than of waxes.

Four laboratory tests of suitability were used in formulating new waxes: (1) The brushing or application characteristics; (2) the temperature at which the wax became soft; (3) the temperature at which it ran; (4) the flexibility, at room temperature, of a layer of the wax

on a piece of paper. No attempt was made to refine these tests, as those made in the laboratory are inadequate, since the real test is the effect of the wax on the percentage of scions that live, the percentage of good unions, and freedom of the grafts from insects and wood rots. The tests made in the laboratory were primarily to show adjustments needed to make the combination of materials workable. Some of the waxes were designed to be applied in the melted condition with a brush and others without melting. A few of the latter class were applied with the hands.

It is unnecessary to list the properties of all the materials used, because most of them are standard articles of commerce. One grade of beeswax, however, gave better results than the others tried. This was a dark-colored, tough wax known as second run or slum gum, and probably contains a considerable amount of propolis, a gumlike material.

Scions were set by the inlay-bark-graft method, two scions per graft. Scion wood of the Stuart variety that was collected and stored as previously described (p. 10) was used. The wax formulas used, the number of scions set, and the percentage of scions growing are given in table 3. Because there were so many different combinations of materials used in making a wax, each wax has been given a serial number to aid in discussing its value. Stocks used in series 1 were *Carya pecan* seedlings of good growth and uniformity from sucker growth from the roots of trees left in an old nursery. These stocks varied from 2 to 4 inches in diameter at the point where the grafts were inserted. The stocks used in series 2 were natural seedlings of *C. pecan* and *C. aquatica* (Michx. f.) Nutt growing along a bayou. The trees were not uniform in size and vigor, but those unsuitable were discarded. No detailed record was kept of the response of the two species to grafting, but it was apparent that the percentage of growing scions was less on *C. aquatica* than on *C. pecan* and that the scions did not grow as rapidly as on *C. pecan*.

TABLE 3.—Waxes used to cover grafts and their effects on percentage of scions that grew and on those having good unions

Wax No.—	Ingredients	Parts by weight	Melting point °C.	Series ²	Year	Scions set	Scions growing	Scions having good unions	Remarks
Formulated material:						Number	Percent	Percent	
1	Rosin	10	55	1	1935	41	56	80	{ Sticky and stringy when melted; was hard to get good coverage; brittle when cold; broke when growth increased size of stock and scion.
2	Beeswax	2	40	1	1936	50	88	90	{ Too thin when melted; hard to get good coverage; brittle when cold. When exposed to heat of sun an oil separated and injured cambium.
	Rosin	10			1935	31	90	60	{ Applied better than any other used. Softened in heat of sun, moved downward so that top of junction of scion with stock was unprotected. Many scions failed to unite at rim of stock and borers damaged many unions.
	Paraffin	2			1936	50	70		{ Many grafts had wood rot.
3	Rosin	10	60	1	1935	100	87	30	{ Softened in heat of sun, and an oil separated and injured cambium. Very few unions complete at rim of stock. Much damage by borers. Many grafts showed wood rot.
	Beeswax	2			1936	54	48		{ Applied almost as well as No. 3; maintained good coverage until union was well established. All unions good at rim of stock. No damage from borers or wood rot.
4	Rosin	10	40	1	1935	28	89		{ Did not soften as badly as No. 4, but was brittle when cold. Borers entered through cracks in wax and damaged some unions.
	Paraffin	2			1936	50	88	81	{ Tale settled out when mixture became too hot and wax assumed characteristics of No. 1; otherwise good. Covered well and maintained coverage until union was complete.
5	Beeswax	10	60	1	1935	46	100	95	{ Applied well; softened somewhat in sun and did not maintain complete coverage. Some scions failed to unite at top of stock; 2 scions broke out.
	Kieselguhr 1	2			1936	52	63	65	{ No borer or wood rot damage.
6	Rosin	10	40	1	1935	50	90	84	{ Sticky and hard to apply; hardened fairly rapidly and remained elastic under surface. Unions were not all complete at rim of stock. Some bore damage.
	Paraffin	2			1936	46	89	76	{ Veryropy when hot, hard to apply, and tended to form bubbles which broke on cooling, leaving holes in the covering.
7	Beeswax	10	60	1	1935	58	90		{ Ropy when hot and hard to apply; hardened quickly and remained elastic when cool; Adheso did not melt readily; at the high temperature necessary to keep the wax in condition for application the Adheso tended to burn.
	Talc	2			1936	52	65	98	{ Melting point was high and material was brittle when cold. Addition of talow in 1936 improved the consistency, but borers did some damage.
8 ²	Rosin	10		1	1935	45	82		{ Somewhat sticky when hot; did not cover as many grafts as No. 5. Unions were not all complete at rim of stock.
	Beeswax	2			1936	46	89	84	
	Naphthol tar	0.6			1936	46	89	84	
9	Rosin	20	55	1	1935	20	90		
	Beeswax	5			1936	50	82	76	
	Cotton pitch	6			1936	50	82		
10	Rosin	10	40	1	1935	15	100	80	
	Beeswax	2			1936	50	92		
	Cuscut glue	1			1936	50	92		
11	Rosin	10	40	1	1935	14	100		
	Adheso	2			1936	50	96	96	
	Kieselguhr 1	1			1936	50	96		
12 ⁴	Wax B-430	10		1	1935	23	74	78	
	Beeswax	12			1936	50	84		
	Kieselguhr 1	1			1936	50	84		
13 ³	Rosin	4	64	1	1935	20	100		
	Wax B-430	1			1936	50	88	86	
	Resin 2	1			1936	50	88		

14 ³	Rosin Wax B-430 Adheso 2 Adheso	4 1 1 1	C4 {	1 1935 1 1936	18 46	83 96	96	{ Hard to get melted, was sticky and stringy; softened in sun but did not run.
15 ³	Wax B-430 Gelowax Rosin	14 12 16	75 {	1 1935 1 1936	26 50	85 80	74	{ Brittle when cold and cracked badly. Borers entered through cracks and damaged 20 percent of the grafts.
16	Rosin Beeswax Kieselguhr 2	10 2 2		1 1935	48	86		{ Kieselguhr grade 2 was ground finer than grade 1, partly destroying sponge-like structure of the particles, and was less efficient as a filler.
17	Beeswax Kieselguhr 3	10 2		1 1935	50	84		{ Kieselguhr grade 3 was ground still finer and was still less efficient as filler.
18	Rosin Beeswax Kieselguhr 4	10 2 2		1 1935	46	78		{ Kieselguhr grade 4 was still finer and less efficient as filler.
19	Beeswax Iron oxide	10 1		1 1935	42	74		{ Applied well and formed good coverage. Reason for failures was not apparent; same formula in 1934 resulted in complete failure.
20	Beeswax Kaolin	10 2 1		1 1935	21	71		{ Kaolin settled out of mixture when hot and did not make a good filler.
21	Beeswax Fuller's earth	10 2		1 1935	22	32		{ Fuller's earth settled out of melted mixture.
22	Beeswax Whiting	10 2		1 1935	49	18		{ Whiting settled out of melted mixture.
23	Beeswax Other (yellow)	10 2		1 1935	20	15		{ Other remained in suspension, but the wax did not cover well.
24	Beeswax Powdered tobacco	10 2		1 1935	28	57		{ Tobacco was added to repel borers; did not serve as filler. Wax was stringy when hot and brittle when cold; apparently not effective as a repellent of insects.
25	Beeswax Cotton pitch Rosin	5 10 10		1 1935	22	70		{ Messy to apply; hardened well on surface and remained elastic. Black color may have been responsible for failures.
26	Beeswax Naphthol tar Adheso	5 10 1		1 1935	21	81		
27	Wax B-430 Adheso	10 10		1 1935	32	72		{ Stringy and hard to apply, but remained elastic when cold; required high temperature to melt and apparently is not stable at this temperature.
28	Wax B-430 Adheso	10 10		1 1935	32	44		{ The addition of the filler reduced the stringiness and wax was easier to apply; high temperature required to melt.
29	Kieselguhr 2 Wax B-430 Beeswax	3 10 10		1 1935	42	74		{ Wax was very brittle when cold; cracked badly and borers entered through the breaks in the wax.
30	Wax B-430 Beeswax	10 4		1 1935	47	40		{ More brittle than No. 29 and less effective.

Footnotes at end of table.

TABLE 3.—*Waxes used to cover grafts and their effects on percentage of scions that grew and on those having good unions—Continued*

Wax No.—	Ingredients	Parts by weight	Melting point	Series	Year	Scions set	Scions growing	Scions having good unions	Remarks
Formulated material—Con.			°C.			Number	Percent	Percent	
31	Gelowax A			1	1935	16	94		{ When warm, wax became viscous and was hard to apply, but was somewhat brittle when cold. The only wax used that was of any value used alone.
32	(Gelowax A—125 Wood rosin 2—125 Kieselguhr 3—10 Wood rosin 1—6 Rosin residue 1—6 Gelowax A—2 Adheso—1 Rosin—8 Cotton pitch—1 Soap—1 Paraffin—10 Gum—10 Adheso—50 Wax B-480—50 Add 1 ml. petroleum ether for each gm. of Adheso			1	1935	17	71		
33				1	1935	19	21		
34				1	1935	20	70		Hard to apply.
35				1	1935	18	72		Very hard to apply.
36				1	1935	18	89		{ Easy to apply and formed good covering, but the mixture deteriorated quickly and did not protect the graft long enough for union to take place.
37				1	1935	38	61		{ Waxes dissolved in ether under reflux condenser. This was the only mixture applied cold that gave satisfactory results. It was difficult to handle.
38				1	1936	50	28		{ Was used as hand wax, but did not stick well and was hard to apply.
39				1	1935	12	25		{ More glycerin than in No. 37 and could not be applied as hand wax; necessary to heat.
40				1	1935	14	0		{ Did not maintain cover more than a few days
41				1	1935	20	63		{ Too soft, and hard to apply; did not maintain cover for more than a few days.
42				1	1936	50	0		{ Sap from stock formed bubbles under coating, which burst and left a portion of the graft unprotected. No filler was used in 1935.
43				1	1936	34	47		{ The solvent or the emulsifier seemed to be injurious to the cambium; set quickly, but bubbles of sap formed under the cover, then broke and left the graft unprotected.
44				1	1936	50	33	12	{ The filler weakened the cover, and breaks occurred through which borers gained entrance.
45				1	1936	46	96	82	{ Wax softened in the sun and moved downward, caving the top of the graft unprotected. Unions were not complete to the top of the stub. Borers gained entrance through the unprotected part at the top of the graft, damaging 14 percent of the unions.

46	Rosin..... Beeswax..... Kieselguhr 1..... Lined oil.....	10 2 1 5	38	1	1936	50	82	56	{Wax softened in the sun. Apparently some injury to cambium from oil. Unions not complete to top of stub. Borers damaged 30 percent of the unions.
47	Rosin..... Beeswax..... Kieselguhr 1..... (Copper resinatc.	10 2 1 7	60	2	1936	50	4	0	{The addition of copper resinatc as a fungicide was apparently injurious. The mixture changed consistently on heating, which may indicate that the copper resinatc was not stable.
48	Paraffin..... Kieselguhr 1..... Tallow.....	2 1 1	40	1	1936	48	94	70	{Wax melted in the sun and did not protect grafts. Many unions not complete to top. Borers damaged 10 percent of the unions.
4	Rosin..... Beeswax..... Calcium carbonate	10 2 1		1	1936	50	88	80	{Calcium carbonate tended to settle out of mixture; wax was then brittle when cold.
50	Rosin..... Beeswax..... Starch.....	10 2 1		1	1936	50	94	90	{Starch tended to settle out of mixture and burned in bottom of melter; wax then became brittle when cold.
51	Flexoresin A..... Wax B-181..... Kieselguhr 1.....	10 10 3		1	1936	48	83	60	{Too soft, melted in sun and left graft unprotected.
52	Wax B-430..... Wax B-181..... Kieselguhr 1..... Wax B-430.....	10 8 1 20	75	1	1936	50	92	88	{Melting point too high; wax brittle when cold. Borers damaged about 5 percent of grafts.
53	Wax B-181..... Adheso..... Kieselguhr 1.....	20 1 3	75	2	1936	24	33		{Melting point too high; wax brittle when cold.
54	Paraffin.....		55	2	1936	50	56	50	{Brittle when cold; softened and an oil separated when exposed to sun; wax then more brittle; oil injured cambium. Very few good unions.
55	Wood rosin 1..... Tallow..... Castor oil..... Ethyl alcohol.....	10 2 1 4	30	2	1936	20	0	0	{Material too soft and ran off the graft before hardening; oil seemed to injure cambium.
56	Wood rosin 1..... Rosin residue..... Tallow..... Castor oil..... Ethyl alcohol.....	10 3 2 1 4	30	2	1936	20	0	0	Do.
57	Wood rosin 1..... Rosin residue 2..... Tallow..... Castor oil..... Ethyl alcohol..... Copper resinatc..... Wax B-430.....	9 3 2 1 4 1 2	30	2	1936	20	0	0	Do.
58	Adheso..... Rosin..... Flexoresin E1..... Kieselguhr 1.....	2 2 4 1		2	1936	50	40		

Footnotes at end of table.

TABLE 3.—*Waxes used to cover grafts and their effects on percentage of scions that grew and on those having good unions—Continued*

Wax No.—	Ingredients	Parts by weight	Melt- ing point	Series	Year	Scions set	Scions grow- ing	Scions having good unions	Remarks
Formulated material—Con.			° C.			Number	Percent	Percent	
59	{ Rosin Beeswax Kieselguhr 1 Pine oil Phenothiazine Beeswax Lanolin Ceresin Japan wax Rosin residue 2 Pine oil Kieselguhr 1 Rosin Beeswax Lanolin Ceresin Japan wax Pine oil Kieselguhr 1	{ 20 6 4 1 0.4 300 16 44 26 4 10 2 30 250 15 45 25 5 2 20	{ } } } } } } } } } } } } } } } } } } }	2	1936	50	8	—	Too soft, melted in sun; oil apparently injured cambium.
60	{ Rosin Beeswax Kieselguhr 1 Pine oil Phenothiazine Beeswax Lanolin Ceresin Japan wax Rosin residue 2 Pine oil Kieselguhr 1 Rosin Beeswax Lanolin Ceresin Japan wax Pine oil Kieselguhr 1	{ 20 6 4 1 0.4 300 16 44 26 4 10 2 30 250 15 45 25 5 2 20	{ } } } } } } } } } } } } } } } } } } }	2	1936	48	2	—	{ Melting point too low; wax melted and ran off the graft; apparently was injurious to cambium.
61	{ Rosin Beeswax Kieselguhr 1 Pine oil Phenothiazine Beeswax Lanolin Ceresin Japan wax Rosin residue 2 Pine oil Kieselguhr 1 Rosin Beeswax Lanolin Ceresin Japan wax Pine oil Kieselguhr 1	{ 20 6 4 1 0.4 300 16 44 26 4 10 2 30 250 15 45 25 5 2 20	{ } } } } } } } } } } } } } } } } } } }	2	1936	50	16	—	Not quite so soft as No. 60, but still too soft.
Proprietary compounds:									
62	Grafting wax 1		55	1	1935	25	96	—	
63	Grafting wax 2		58	2	1936	50	52	—	
64	Grafting wax 3		40	2	1935	30	83	—	
65	Grafting wax 4			2	1936	50	62	—	
66	Grafting wax 5			1	1935	30	80	—	
67	Grafting wax 6			2	1936	50	74	—	
68	Grafting wax 7			1	1935	42	64	—	
69	Grafting wax 8			1	1935	51	90	—	
70	Grafting wax 9		25	2	1936	50	16	—	
71	Grafting wax 10		25	2	1936	20	15	—	
72	Asphalt pruning compound		25	2	1936	18	11	—	
73	Asphalt emulsion 1			1	1935	29	83	—	
74	Asphalt emulsion 2			1	1935	32	0	—	
75	Asphalt emulsion 3			1	1935	30	0	—	
76	Paraffin emulsion 1			1	1935	30	0	—	
77	Paraffin emulsion 2			1	1935	24	42	—	

78	Cotton pitch emulsion	1	1935	26	50			
79	Plasticized linseed-oil pruning compound	1	1935	26	4			
80	Orange shellac	1	1935	31	39			

¹ Most of the materials do not have a definite melting point. Cones of the material 2 inches high by 1 inch wide at the base were placed in an oven. The temperature at which the cone began to flatten and spread was recorded and referred to as the melting point. The temperature at which the material could be applied with a brush was usually higher; this was determined for a few waxes by inserting a thermometer in the melted wax. For waxes Nos. 2, 4, and 6 the application temperature was approximately 75° C.; for waxes Nos. 1, 3, 5, and 7, from 90° to 97°; and for waxes Nos. 82 and 83, approximately 130°.

² The stocks used in series 1 were more vigorous and uniform than those in series 2. The effect of the waxes should be compared with wax No. 5 for each series.

³ 1 part of kieselguhr grade 1 was added to the formula in 1936.

⁴ 1 part of beef tallow was added to the formula in 1936.

⁵ The waxes Nos. 36, 37, 39 to 44, 55 to 57, 68 to 80, inclusive, were applied without heating.

RESULTS

In 1935 and 1936 four of the waxes, Nos. 5, 7, 10, and 11, resulted in 90 percent or more living scions; four other waxes, Nos. 2, 6, 9, and 62, were in this class in 1935, but did not give as good results in 1936; Nos. 31 and 66 resulted in 94 and 90 percent of living scions, respectively, in 1935, but through error were not used in 1936; Nos. 45, 48, 50, and 52 were not used in 1935, but resulted in 92 percent or more of growing scions in 1936.

Considered from all standpoints, wax No. 5 was the most satisfactory of those tested. Only 5 scions of 146 set in series 1 and covered with this wax failed to grow; 1 was damaged by a cow, and the others did not grow because of failure of the stock to form callus or even water sprouts. All living scions formed unions completely to the apex of the stub and the new growth advanced over the wound, firmly anchoring the scions. There was only one instance of borer damage and that was on the scion damaged by the cow. No evidence of wood rot was found 2 and 3 years after the work was done.

Results from the use of wax No. 7 were almost as good. Only 6 scions of the 108 set and covered with this material failed to grow. At one time during the 1935 season the mixture became too hot and the talc settled out; this may have been responsible for the failures. Where rosin and beeswax were used without a filler (wax No. 1) the percentage of growing scions was only 56. The settling of the talc from wax No. 7 resulted in a wax having characteristics similar to those of No. 1.

Waxes Nos. 5 and 7 are very similar, having rosin and beeswax in the same proportions (10 : 2), but they differ in that kieselguhr was used as the filler in No. 5 and talc in No. 7.

The grade of kieselguhr used was a white, fluffy, amorphous powder having friable, spongelike particles and a large surface area in proportion to its weight. It was very efficient in making the wax pliable and elastic and in reducing the sticky stringiness which a beeswax-rosin wax without filler has when melted to the proper consistency for application. The filler did not greatly affect the melting point of the wax but by increasing its "body" did prevent it from becoming soft enough to run when exposed to the hot sun. The talc used was the grade sold as Purified Talc, the particles of which were crystalline and even though finely divided did not have the large surface-to-mass ratio of the kieselguhr.⁵

Various other filler materials were used with different results. Lampblack as a filler for the rosin-beeswax mixture resulted in a material of good brushing consistency, which covered better than any other used. The percentage of growing scions was lower than where kieselguhr or talc was used, apparently owing to greater absorption of heat from sunlight. When the air temperature ranged from 90° to 95° F., wax with lampblack as the filler exposed to sunlight became soft enough to run from the graft, while under the same conditions wax with light-colored fillers softened slightly but did not run. When cones of the materials were heated in an oven in the laboratory, there was no apparent difference in the temperature at which mixtures with lampblack and kieselguhr as fillers became soft enough to run. Deter-

⁵ After this experiment was completed, a wax having aluminum powder as the filler instead of kieselguhr but otherwise the same as wax No. 5 was tried 1 year only. The results were equal to those obtained with wax No. 5.

minations were not made of the temperatures of grafts covered with these two materials when exposed to sunlight.

Wood-rot infection took place very frequently on grafts where one or both of the scions failed to grow and almost as frequently on stubs where the scions had failed to unite at the top leaving a projecting stub that died. It is of interest that in series 1, grafts covered with the black wax were infected only by *Panus rudis*, whereas the majority of infections in the grafts covered by light-colored waxes were by *Schizophyllum commune*. In series 2, however, almost all of the infection of the grafts was by *P. rudis* without relation to the covering material.

The addition of linseed oil to wax No. 5 to make wax No. 46 reduced the percentage of scions that grew and of good unions formed. The addition of linseed oil to wax No. 3, which had lampblack as the filler, reduced the percentage of scions that grew more than did its addition to wax No. 5 (1934 data, not shown in table 3). Apparently the oil separated from the other ingredients and injured the cambium. Furthermore, the wax cover softened in the sun and moved downward, leaving the top of the stub without sufficient protection. This resulted in 31 percent of the scions that grew being injured by borers, and in many cases wood rot followed.

The addition of tallow to wax No. 5 to make wax No. 45 did not materially alter the percentage of growing scions in series 1, but good unions were fewer. The covering softened in the sunlight and failed to maintain complete protection at the top of the graft, so that borers injured about 14 percent of the unions.

The substitution of paraffin of 55° C. melting point in wax No. 6 for the beeswax in wax No. 5 resulted in a thin and nearly transparent wax when melted, which made more difficult a complete covering of the graft. The wax was rather brittle when cold and tended to separate in the sun. Although in some instances the percentage of scions growing was as good as that obtained with the beeswax in the mixture, the percentage of good unions was consistently lower. Paraffin used alone (No. 54) was very unsatisfactory; it is a mixture of hydrocarbons that separate at a temperature of 30° to 36° C.; apparently, one of the constituents was an oil that injured the cambium.

Objections have been raised to the use of a heated wax on the grounds that it is difficult to keep it in condition for use or that it may kill the cambium. No evidence was found of injury to the cambium that could be assigned to the heat of the wax. Waxes when applied varied in temperature from that of the air to 130° C. Wax No. 52 had to be heated to 130° for application, which is considerably above the temperature usually considered fatal to most plant cells, but 92 percent of the scions grew where this wax was used. The best results were obtained with wax No. 5, which had an application temperature of 95° to 97°. Some protection from the heat may have been afforded the cambium by the insulation of the bark covering it, but this perhaps was not very effective in many instances, because most of the bark was pared away before the scion was inserted. The wax was applied to the graft as a thin layer, seldom if ever more than one-sixteenth of an inch thick. The heat carried by this thin layer of wax perhaps was insufficient to raise the temperature of the cambium to the lethal point.

Some difficulty was encountered in keeping the wax melted during the first season of work. A melter which prevents this trouble was designed which made it easier to keep the wax melted than to keep in condition for use a wax designed to be applied without heating if thinned with a volatile thinner.

Most of the melters tried were unsatisfactory either because the flame was frequently extinguished by the wind or because the alcohol in a lamp enclosed in the heated chamber expanded, overflowed through the wick tube, and ignited. Several times solder joints were melted, and a few times the wax caught fire.

A melter, consisting of a small pail in which the wax was held suspended in the top of a larger outer pail, with an alcohol lamp placed in the bottom of the large pail, was modified to correct the trouble. A false bottom with a hole in its center slightly larger than the wick tube of the burner was placed in the outer pail at such a height that when the burner rested on the true bottom the wick tube extended through the hole in the false bottom. The fuel reservoir was thus separated from the heated compartment by the false bottom. The fuel reservoir was further protected from the heat by large ventilating holes in the side of the outer pail below the false bottom. Ventilation for the flame was provided by small holes in the false bottom and in the sides of the outer pail near the top.

Of all the materials used none that could be applied cold was satisfactory, although wax No. 36 appeared promising in 1935. This formula could not be duplicated in 1936, because the waxes could not be completely dissolved in the petroleum ether even when three times as much ether was used. Other materials tested included the asphalt emulsions reported by Cardinell (3) as satisfactory for use in grafting the apple; the paraffin emulsions reported by Stoutemeyer (33) for use in grafting arborvitae; the alcohol-rosin mixtures reported by Granett⁶ for wound dressings; and the rubber latex reported by Marshall (20) as also giving good results for wound dressings. These materials were unsatisfactory in pecan grafting largely because they failed to form a good cover owing to sap exuding from the cut surface of the stock. Occasionally they seemed to cause injury to the scion or stock.

Rubber latex and plasticized tung oil quickly formed elastic, tough covers, but where these materials were used the percentages of scions growing were low. It is possible that some combination of these with other materials may prove of value. Since this work was completed, notice of the use of rubber latex with flake aluminum for grafting apples has been published (32). In 1938, 1 part of flake aluminum to 20 parts of rubber latex, by weight, was used in comparison with wax No. 5 under similar conditions. Sixty-four percent of the scions covered by the aluminum-latex combination and 100 percent covered by wax No. 5 grew.

The use of copper resinate, phenolthiazine, and tobacco in the covering material as fungicides or insecticides lowered the percentage of living scions. It was not determined whether these materials were toxic or whether the failure of the scions to grow was due to some physical effect of the mixture. In one mixture, wax No. 47, copper resinate, was added to wax No. 5, which had given excellent results. The mixture changed consistency on heating and gave poor results.

⁶ GRANETT, PHILLIP. THE USE OF RESIN IN A LIQUID TREE WOUND DRESSING. Unpublished thesis. Copy on file Rutgers (N. J.) Univ.

DISCUSSION

There seems to be no valid reason why results in grafting the pecan should not be as good as those with other fruit trees, although some details of the procedure should be varied when working the pecan. Difficulties encountered in the past apparently have been largely due to a lack of understanding of the response of the tree to severe pruning, such as is necessary to accomplish the substitution of a new top for the old one by grafting. The response of the pecan to wounding and its subsequent growth seems to closely parallel that of the apple; the establishment of union between the callus of the stock and scion is fundamentally the same process. Growth of the tissues following the grafting of the pecan seems to follow the same general process as that following decapitation of a branch. Any portion of the decapitated branch or stock extending beyond the lateral (branch or scion) dies and many such dead stubs are invaded by wood-rotting fungi. In order to avoid dieback and subsequent wood rot in grafting it is exceedingly important to obtain union between the scion and the stock in such a manner that no portion of the stock extends beyond the most distal point of union.

Trees low in vigor do not respond to pruning in the same way that vigorous trees do. Production of wound tissue is slow and may be insufficient for a union of the stock and scion. Growth subsequent to pruning and grafting may be weak and the tree may fail to produce enough foliage to carry it through the top-renewal period free from sunscald, wood rot, and insect damage. Such trees should be fertilized or otherwise treated so that they will be vigorous before an attempt is made to top work them.

For the production of wound tissue sufficient to accomplish union the pecan apparently requires temperatures higher than those prevailing during the dormant season; therefore, grafting during the dormant season is usually attended by unsatisfactory results. Of the methods of grafting that may be used during the growing season, modifications of the bark graft are most promising. In this study the inlay-bark graft resulted in the highest percentage of both living scions and good unions. Where the wax used to cover the graft was suitable, this method resulted in the establishment of all unions at the rim of the stock; no dieback occurred on any of the grafts, and they were so mechanically strong that none were broken out at the union by wind. A high percentage of grafts set by other methods, which did not have unions at the rim of the stock, did break out.

Setting of scions by the inlay-bark-graft method is less expensive, as it takes less time and the cost of material for covering the grafts is less than for other methods used except the bark-slot method. Waxed cloth for covering and securing the scion is unsatisfactory because applying it requires too much time and material and its use results in poor unions. During cool periods in early spring the waxed cloth and the hand wax become hard and are difficult to use; during warm weather the wax in the cloth and the hand wax become soft and sticky, adhere to the hands of the operator, and interfere with the work.

During the progress of this work the larvae of the American plum borer and of the pecan borer caused the failure of many scions and weakened the union of many others. These insects caused no damage to the inlay-bark grafts where suitable wax was used. Apparently the insects gain entrance to the grafts through breaks in the wax cover,

and the elimination of, or reduction in, the number of cracks materially reduces the damage. With the inlay-bark-graft method the scions can be fitted to the stock so closely that a complete cover of wax is easily obtained. Growth subsequent to grafting expands so uniformly over the entire area of the union that no opportunity for entrance of the borers is offered, even after the wax cover is ruptured.

SUMMARY

Critical examination of numerous pecan trees top worked with poor results showed the need of a method of grafting that would insure a large percentage of the scions united with stock at the rim of the cut and a reduction in the amount of damage from wood rot and borers.

Different methods of bark grafting were tested. The inlay-bark graft was found to give a higher percentage of good unions than all other methods used.

These tests showed the need of a suitable covering for the grafts. Eighty different materials were tested and two waxes were found that gave a high percentage of growing scions and of good unions free from borer and wood-rot damage. The waxes were similar in that each was composed of 10 parts of rosin, 2 parts of beeswax, and 1 part of filler. The better of the two had a good grade of kieselguhr as the filler and the other had talc.

Oils used in the wax and which separate from it seem to be injurious to the cambium of the pecan.

No satisfactory covering material was found that could be applied without heating. The failure of some of the materials applied cold was perhaps due to rupture of the covering material before it had an opportunity to set, caused by the sap exuding from the cut stock.

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